How a Tornado Strike in New Castle, Indiana, in 2020 Would Impact the City

An Honors Thesis (HONR 499)

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Abstract

Tornadoes are destructive forces of nature that can have major impacts on our lives, especially if they hit a major city. Therefore, in recent years, scientists have been analyzing how GIS can be used to study tornado impacts near towns and cities. This document looks at the amount of damage New Castle, Indiana, would see if a tornado, similar to a tornado that hit the city in 1917, struck today. To see what would happen, a path of the tornado was made, then placed in GIS and joined with 2018 parcel data of the city. The results showed that a tornado would affect large numbers of properties in the city, with up to 718 parcels affected and damages exceeding $50 million USD (2018 dollars). Limits on the data include the inexact nature of mapping tornado paths and the old data used. The results, however, showed that not only would a tornado strike in New Castle be devastating, but that GIS can show just how exactly devastating a tornado strike is.

Acknowledgements

First, I'd like to thank the Henry County Historical Society, and Henry County's GIS Administrator Bruce Atkinson, for their help with the thesis. They provided the resources, and tips, needed for me to make a map of the tornado in the first place. Without them, it would have been much more difficult to make the path. I also want to thank Dr. David Call for being my thesis advisor. He is a wonderful professor who always kept me on track with my project, and always offered good advice on where I can go from here. I want to thank my best friends for keeping me on track and for reminding me that even when life seems stressful, there's always something to smile about. Finally, I want to thank my parents, for reminding me that I can do anything I put my mind to.

Process Analysis Statement

The process of using GIS to study how a tornado would affect New Castle, Indiana can be described as difficult, especially with the Coronavirus causing some problems. The origin of the idea, however, was simple. Years ago, I became fascinated with two ideas, which are historical analyses of tornadoes and the social impacts of tornadoes, i.e. how much damage they can cause and the results of these events. The New Castle, Indiana, tornado of 1917, in particular, was fascinating because it happened in my hometown. The tornado caused massive amounts of devastation just a few blocks from where I originally lived. Since the tornado hit so close to home, I wanted to see what would happen if a repeat of the storm happened today. And with the use of GIS, I finally had the potential to do just that.

Since the goal was to understand the cost and number of properties affected by a tornado in New Castle, the best way to do this was to use GIS. But to do this, I needed a path of the tornado. This was because I needed to overlay the tornado's path onto the city to see where and what it would have affected. After reading several articles, newspapers, a book, and analyzing a few photographs, I then sketched a preliminary map of the tornado. I then contacted the Henry County Historical Society to confirm if the path was close to what they expect based on descriptions of the storm. After meeting up with the Historical Society and looking at more photographs and newspapers for several hours, I then compared the map they made to the damage photographs and literature of the storm. Because the map given to me matched well with the damage photographs, newspapers and literature, I kept the map.

Once the path was confirmed, I then went to the GIS portion of the project. While I was communicating with Henry County's GIS administrator on getting more recent data, I decided to get some older data in case I need to. I went to a website that contained GIS data of Indiana, including land parcel data from 2018. I then uploaded it onto ArcMap 10.7.1., where I then joined the shapefiles - the files that actually show the parcels - with the geodatabase data, which contain information about the parcels themselves that I needed for the project. This required troubleshooting and double-checking my work several times, to make sure I joined the geodatabase data with the shapefile data with the right attribute. After successfully joining the two files, I then went to Illustrator and sketched a tornado path onto a topographic map. I then used the website that had the topographic map for georeferencing, where I took the map, inserted it into ArcMap, and placed key coordinates onto the map to match it to the shapefile. This led to me successfully placing the path onto the shapefile, allowing me to then make layers based on the parcels affected. The process took two days to finish.

One lesson of the thesis is that it's important to figure out what needs to be done in the first place. One problem that I had was that I was not sure how to approach the project in the first place. I knew that I needed data of the city's properties, and I knew that I needed to make layers and joins from past GIS classes, but I wasn't sure where to get much of my data in the first place. Another important lesson is that once a goal is set, dates need to be assigned and kept to. It is very likely that had I kept to my dates regarding my thesis, my thesis would be better in quality, which is especially important, as the Coronavirus caused major problems with the project. This was especially important, as the GIS portion took a few days to function, mainly due to checking my

work. Yet another lesson that I learned quickly was that it was a good thing that I had a backup plan. Some of the maps that I used in Illustrator could not work, since I had no coordinates to make the maps work for georeferencing. That meant looking up for websites that had topographic maps, which would have coordinates. Because the website I used had coordinates that I could place on the map, that allowed me to successfully georeference the map. The lesson also applies to me collecting older data, since I was concerned that I would not be able to get anything to one of my contacts in time. In short, the project shows that having a goal and how to get there, time management, and having a backup plan are all thoughts I had to consider with the thesis.

1. Introduction

1.1 GIS and its Uses

Tornadoes are some of nature's most destructive forces. The strongest tornadoes can have paths of up to one mile wide and wind speeds above 200 mph. Because of their destructive potential, studies have been done to figure out how to lessen their impacts. One way to lessen a tornado's impacts is to analyze tornado paths and see what was impacted. This can be done with GIS, or Geographic Information System. GIS is a mapping program, first made in the 1960s by Canada (Tate, 2018). Ever since then, the program became widespread. The program allows for analyzing data of a location for purposes ranging from social studies to physical studies. This is why GIS can be used for tornado studies.

One way GIS is used for tornadoes is to analyze past tornadoes and look at how they could impact cities. For example, in 2000, researchers looked at how a hypothetical F5 tornado, similar to the Moore, Oklahoma tornado in 1999, would affect the Dallas-

Fort Worth region in Texas. Using GIS, data from the North Texas Government, and tornado path data from the 1999 Oklahoma tornado outbreak, the study placed several tornado paths through the city. The worst-case scenario would damage tens of thousands of buildings and cause billions in losses (Rae, 2000). Another GIS study looked at how an F4 tornado would affect the city of Norman, Oklahoma. In that study, the author took the path of an F4 tornado that, on May 23, 2011, formed near the city. When the path was placed over the city, the study showed that damages would exceed $800 million, with thousands of buildings destroyed (Berríos, 2017). While casualties were not modeled in both scenarios, circumstantial evidence from past tornadoes, such as the Joplin, Missouri tornado of 2011, indicate that substantial casualties from a tornado hitting these cities would be likely. In short, GIS has been used to model tornado paths in large locations.

One major problem with these studies, however, is that not many GIS studies look at the smaller cities. No one looks at any smaller towns and cities that might be hit by a violent tornado. They also don't look at past storms that have hit in the past, such as tornadoes that have hit prior to the 1950s. This could be for a variety of reasons, including lack of data for tornado paths before 1950, or the lack of a need to look at tornadoes that have hit smaller cities. Either way, it is becoming more important to look at how GIS can be applied to tornado paths, whether it's for large cities or small towns.

1.2 Context of the New Castle Storm

Indiana is vulnerable to tornadoes. The state, on average, sees 22 tornadoes a year. It's lower than the numbers seen in Oklahoma and Illinois ("U.S. Tornado Climatology", n.d.). The state, however, does have a history of facing violent tornadoes. In fact, some of America's worst tornado outbreaks have taken place in the Hoosier state,

such as the 1974 Super Outbreak. In that outbreak, 148 tornadoes touched down in 13 U.S. states. Of that number, 21 tornadoes touched down in Indiana, killing 47 people ("April 3rd, 1974 Super Outbreak", n.d.). Henry County, Indiana, was one county struck during the 1974 Super Outbreak. Kennard was struck by a violent F4 tornado during the 1974 Super Outbreak. One person - a baby - died in the town, and 70% of the city was destroyed ("Violent Tornadoes in Indiana", n.d.). So not only is Indiana vulnerable to tornadoes, but Henry County itself does have a history of tornadoes.

While New Castle, Indiana, did not suffer a tornado strike in the 1974 Super Outbreak, the city itself is vulnerable to violent storms. On March 11, 1917, at 3:02 pm, a tornado touched down on State Road 38, just west of the city. It moved in a southeasterly direction, passing through multiple streets and even hitting the South School and Rolling Mill plant (H., n.d.). It moved through 20 city blocks, nearly the whole city, in less than 3 minutes. It then exited the city and moved south of Hagerstown, before lifting just to the west of Greens Fork, Indiana, in Wayne County (Day, 1917). The storm claimed 24 lives and injured 100 others (NOAA). To make matters worse, before the tornado struck the city, it was a thriving community. The Rolling Mill plant was one of Indiana's largest steel mills, and the city hosted a large number of greenhouses. The city was, in fact, nicknamed the "Rose City" because of these greenhouses. The city was never the same after the tornado struck (H., n.d.).

Today, New Castle might not be as thriving of a city, but it's still a major town. The 2010 Census revealed that New Castle has around 18,000 people in the city. It hosts several schools, including New Castle High School and the country's largest fieldhouse. The city hosts a large plaza, known as the New Castle Plaza. The city's location on State

Road 38 and State Road 3 means that traffic is common through the city. In short, the city has many important buildings and a large number of people.

Therefore, a violent tornado hitting the city would cause serious amounts of damage, since so many people and so much property is in the city. However, the big question is, if a tornado did hit the city, what would it look like? How much damage would be caused? Because the city and county have a history of violent tornadoes, looking at how a tornado would impact the city is necessary.

2. Methodology

The first major step in figuring out how much damage a repeat tornado would cause to New Castle would be to map the path of the storm. Up until now, only general details were given about the path of the storm. It was known that the tornado moved in a southeast direction, starting on State Road 38 and hitting multiple streets on the southern side of town, including Lincoln Avenue, 18th through 25th streets and Grand Avenue (H., n.d.). Articles written about the storm said that its path was a few blocks wide at the widest (Day, 1917). Damage photos helped confirm some of the locations hit by the storm. However, some of the damage photos that could be used to show what path the tornado took did not have addresses on them, and some didn't even explain what street the photos were taken. For example, the postcard showing damage to the old South School, in the city, did not have an address (Figure 1). Damage photos of the Rolling Mill plant didn't reveal the exact location of the storm either. In order to map the storm's path, more data were needed.

There was also a need to figure out where to start and stop the path. It's understood the tornado moved out of New Castle, moving eastward and paralleling State

Road 38. From there, it hit homes south of Hagerstown and stopped near Greens Fork, in Wayne County (NOAA). However, since the tornado's path crosses through the countryside, it would be difficult to figure out the exact width and path of the tornado. Since the main concern is the fact the city of New Castle was struck by the tornado, it made more sense to focus on New Castle and not focus on the rest of the area. Therefore, the study focused on New Castle and not the rest of the county.

2.1 Mapping the Storm

To figure this out, the author started with the general information of the storm. It was known the storm started on State Road 38, west of New Castle. The storm moved through Lincoln Avenue, 18th through 25th streets, and Grand Avenue (Radford, 2013). Figure 2, which shows a map of New Castle, shows those areas are south of Broad Street, which passes through the downtown area. The storm was also stated to have caused damage on Sixth Street, Eleventh Street and Twelfth Street, which are south of Broad Street and in the western side of town (Perry, 2009). This led to a preliminary map that showed the path of the storm starting on State Road 38, identified by Figure 3, where the red path indicates where the tornado's path was located, and the orange outlines showing the potential error of the tornado path. The error was arbitrary, but it extends out about 500 feet from the red line, since I was trying to account for damage that took place in other locations besides A. Avenue and Lincoln Avenue.

The map was verified by the Henry County Historical Society, which provided another map of the tornado. Once a better map of the tornado path was received by the Henry County Historical Society (Figure 4), the verification stage came into being. The map showed a path similar to the one sketched in Figure 3. Images of the tornado showed

that much of Lincoln Street had suffered damage (Figure 5). The South School had a collapsed roof, several collapsed walls, and damaged windows, indicating that if the tornado had not struck the building, its wind field was large enough to damage it (Figure 1). Finally, photographs of D Avenue show complete devastation, particularly after 20th Street (Figure 6), and A Avenue also shows substantial damage, such as collapsed roofs (Figure 7). This suggests a wide wind field for the tornado as it was exiting the city, although it's just as likely that many of the buildings were not well-constructed and thus collapsed near the tornado's wind field. This helps verify Figure 4's depiction of a widening tornado.

Newspaper articles written about the storm provided additional measurements of the storm's path. The Indianapolis Star, one day after the tornado struck, published a death and injury list of people affected by the storm. Some of the fatalities and injuries had addresses associated with them, or general locations showing where they were found (Green, 1917). After typing the addresses on Google Maps, it was noted that some of the homes that were in New Castle would have been in the tornado's wind field, as indicated by the tornado path. This helps verify some parts of the tornado's path.

Finally, old maps helped show where some of the locations in the photographs were. Sanborn maps are the best maps to use for historical mapping. This is because the maps were originally used for fire insurance policies, so detailed mapping records were kept ("Union List of Sanborn Maps", n.d.). As it turns out, Sanborn maps of New Castle, in 1914, help show the layout of the city before 1917. One map, on Figure 8, showed that the Rolling Mill Plant was located near Broad Street, outside of New Castle. Another Sanborn map, this one showing the entire city of New Castle shows that the Bentley

Greenhouse, one of the greenhouses struck by the tornado, was located off 14th street (Figure 9). That puts it right in the middle of the tornado's path on Figure 4. Another map shows that the South School was located on a block between C and D Avenue (Figure 10). Since D Avenue was impacted by the storm, this means the school was in the path of the tornado when it was hit. The maps showed that the reason some of the locations suffered damage in the storm was that they would have been in the path of the tornado.

Based on all the data shown, Figure 4 seems to be accurate. It is believed the tornado started on the northwest side of town. It first hit the Rolling Mill plant, causing significant damage. The tornado then hit Sixth Street through 12th Street, before weakening slightly as it moved through Lincoln Avenue. Buildings near Lincoln suffered some major damage, with pictures indicating the tornado having destroyed roofs and shattering windows in some homes. The tornado then hit Bentley's Greenhouses, between South 14th and A Avenue, destroying the greenhouses. Based on damage photographs of A, C, and D Avenues, the tornado then grew in size as it moved through the southeastern corner of the city, causing significant wind damage to the area. In short, it missed downtown and instead hit several industrial and residential areas.

2.2. Applying GIS

After figuring out what the path of the tornado was, I then had to figure out what would be the best way to measure damage estimates of the tornado. I deduced the easiest way to measure the damage was to see what land parcels, and buildings in those land parcels, would be affected if a tornado path was laid on the parcels. After deducing that I would need land parcel data to figure out how much damage would take place, I downloaded land parcel data and their metadata - the data sets that describe what the land

parcel data contain - made in 2018. The coordinates are in UTM, or Universal Mercator form, i.e. the data use meters as coordinates. The files were also downloaded with metadata that helped identify what numbers correlated with which structures.

After opening up ArcMap 10.7.1, I then opened the files associated with the land parcel data and then joined - "connected" - two different datasets via similar attributes in their respective attribute tables - the geodatabase data with the shapefile data via the files' addresses, since the addresses differed in name and number and thus were more likely for a successful join. Once the join was made, I then made a layer specifically focused on New Castle, by going to the attribute table calculator and typing in a formula that allowed for specifically finding variables relating to New Castle. This allowed me to find all the attributes related to New Castle, of which there were around 14,000 parcels related to New Castle. Once that was finished, I then made a new layer for New Castle. In short, I used the attribute table to form a new layer.

Since the tornado path isn't in GIS form because it took place in 1917, this meant I had to figure out the coordinates of the storm through other means. That meant placing a map of the storm over a map of New Castle in Adobe Illustrator. To do this, I took a topographic map of New Castle, complete with coordinates, and then downloaded it onto Adobe Illustrator. After sketching out a map of the path onto Adobe Illustrator, I then took the path of the storm and placed it in ArcMap. Since the image did not have coordinates, I had to georeference the image, i.e. I had to assign coordinates to the image. Fortunately, the map website Topoquest that contained certain locations on the map had coordinates of several locations, including Hernly School, Weir School, the New Castle High School, and one of the fire departments, assigned to them. After converting the

coordinates to UTM using a decimals-to-UTM calculator, I then georeferenced the image onto the datasets in ArcMap. Once the georeference was finished, I then used an attribute selection tool, and used the selection by polygon tool, to trace the path of the storm. After doing this, I then made a new layer for the tornado path and made different-colored layers for each type of parcel struck by the tornado. In summary, using Adobe Illustrator and georeferencing, I was able to join the tornado path to the parcel shapefiles and make a map.

3. Results

The results, represented on Figure 11, show that a tornado hitting New Castle would have some serious consequences. For one, multiple important locations would be hit. The tornado would have started in an area where there are now factories, just to the west of New Castle. The path of the storm also moves through a large plaza close to State Road 38, where many people go to shop, potentially putting many lives at risk. As it crosses over State Road 38, it would be passing through traffic, putting drivers at risk. Additionally, the tornado would be passing over many residential areas, putting many more lives at risk. Without even looking at the numbers, one could deduce that a tornado hitting New Castle would be dangerous.

In terms of numbers, the tornado would cause serious losses. The map shown in Figure 11, uses different colors to indicate what parcels would be impacted. For example, “red” indicates residential single-family homes, “yellow” indicates industrial structures - such as factories - and “lavender” talks about commercial structures, such as stores. The map shows several yellow parcels - industrial facilities, like factories - affected by the tornado, as well as large numbers of red “dots,” implying that large numbers of

residential homes are affected by the storm. This suggests that most of the parcels affected contain large residential buildings. Using statistical analysis for the total cost of the parcels and improvements, i.e. finding the sum and average of the prices, show that the total costs of the parcels, and the buildings on top of them, would be exceeding $57 million (2018 USD), as indicated by Figure 12. The maximum value of over $5 million (2018 USD) comes from the industrial centers impacted by the tornado, such as the factories to the west of the city. Additionally, 718 parcels would be affected, based on the attribute table for the tornado path layer. Of that number, most of the parcels affected - 548, or around 76.3% of the parcels – contain residential single-family buildings. Another 40 parcels - 5.57% - are commercial parcels, i.e. they have stores and places of business. Table 1 shows what parcels are affected and the number of parcels affected for each type. In short, hundreds of parcels and tens of millions of dollars of property would have been affected by the tornado.

In summary, the tornado would be moving through a large number of buildings, including residential, commercial, and even a few industrial structures. Because the tornado would be hitting so many structures, total costs could be high, reaching $57 million (2017 USD).

4. Limitations

The study shows just how dangerous a tornado in New Castle can be. As with all GIS studies, however, some limitations are in existence. First, as explained before, there is no exact path for any tornadoes, but this definitely holds true for tornadoes that took place before 1950. The Storm Prediction Center, which deals with studying and forecasting severe weather events, only records GIS data for tornado paths from 1950 to

today. This means that one would need to use pictures and records to figure out the starting and ending coordinates of the tornado path. This process is not exact because tornadoes can cross through the countryside and vary in strength and size. Therefore, a tornado might actually have different path characteristics than what was described or found. Furthermore, even with starting and ending coordinates of the tornado's path, figuring out the exact path of the tornado is not an exact science. Even though a tornado's funnel can be only a few feet wide, its wind field could be very large. The Mulhall, Oklahoma tornado of 1999 was around one mile wide, yet winds of up to 96 mph (43 meters per second) covered a diameter of over four miles (Wurman et. al., 2007). This, combined with possible structural flaws with many buildings during that time, explains how, even though descriptions of the New Castle tornado suggested a funnel that was only a few blocks wide, the damage shown suggests a wind field much larger in size. In other words, figuring out the tornado's path is inherently difficult, due to historical reasons.

Another major problem is the fact that the data used are not recent. The data sets are from 2018, with them being added in 2019. This is a slight problem, since population and price values could have changed between 2018 and 2020. Since 2018 was only a short while ago, however, it still works. Georeferencing is another problem, as converting coordinates from one coordinate system to another can result in differing values. This is important, as in New Castle, the Illustrator map matches up with the roads, but as the map moves further from the center of the city, the roads don't align accurately, implying less accuracy. Since I wanted to look at New Castle, however, this is not as problematic.

Casualties were not modeled with the tornado strike. It's difficult to model casualties because of the inexact nature of how people will react. On the one hand, since the tornado would be passing close to downtown and through many residential and commercial areas, hundreds of people could be exposed to the tornado path. Wurman calculated that a violent tornado hitting a large city, like Chicago, could cause thousands of casualties because of the large number of people congregated in those areas (Wurman, 2007). On the other hand, tornado warnings have gotten better in recent years, as the average lead time for tornadoes is around 14 minutes today, compared to three minutes around 40 years ago (Penn State, 2018). One study suggests that those lead times have led to significant reductions in casualties (Simmons, 2008). Additionally, even if a violent tornado hits a city, not everything is destroyed. As Figure 1 shows, though the South School was within the tornado path, the building was not completely destroyed. Tornadoes have also hit homes, only for the occupants to survive because they're in a sturdy closet or other structure that survives (Associated Press, 2020). So, casualties are too difficult to accurately model.

5. Conclusion

GIS has proven to be a useful tool in studying how tornadoes impact cities, and that still holds true. The goal of this study was to see how a repeat of a tornado that hit New Castle, Indiana in 1917 would impact the city today. Using photographs and coordinates, a map of the tornado path was made and placed in GIS, to see the results. The study shows that a repeat tornado would cause major damage in the city. An estimated 718 parcels would be affected by the storm, with many of these parcels - over 500 - containing either residential buildings or commercial buildings. Damages would be

over $57 million (2018 USD). While casualties are hard to estimate, the fact that a large number of buildings would be impacted by the storm suggests that the number of people affected could be large. Limitations for the study include the inexact nature of historical tornado paths, issues with georeferencing and using slightly aged data, and the uncertainty of casualties from the event due to variables ranging from the number of parcels affected to warning times. Overall, however, the study shows that a tornado strike in New Castle, similar to the one in 1917, would prove to be a dangerous situation for New Castle, Indiana. The implication of the study is that the city's residents, and any city vulnerable to tornadoes, should have plans in place in case a tornado does hit a city.

Figures

Figure 1: The South School, in this postcard, did not have an address posted on it, making it difficult to figure out where the school would have been. Source: http://www.gendisasters.com/indiana/21731/new-castle-in-tornado-mar-1917-heavy-destruction-property

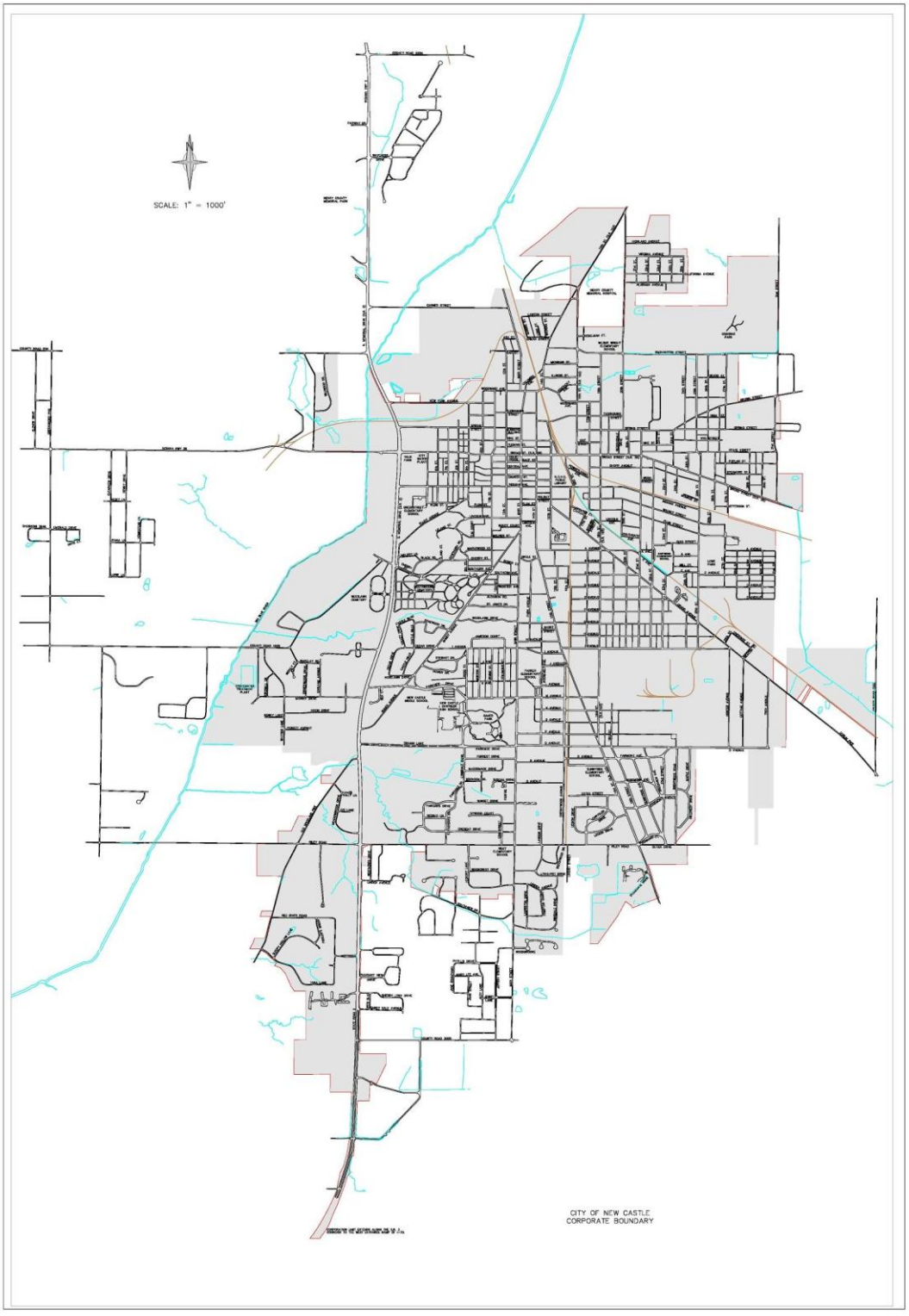

Figure 2: Map of New Castle. Source: cityofnewcastle.net.

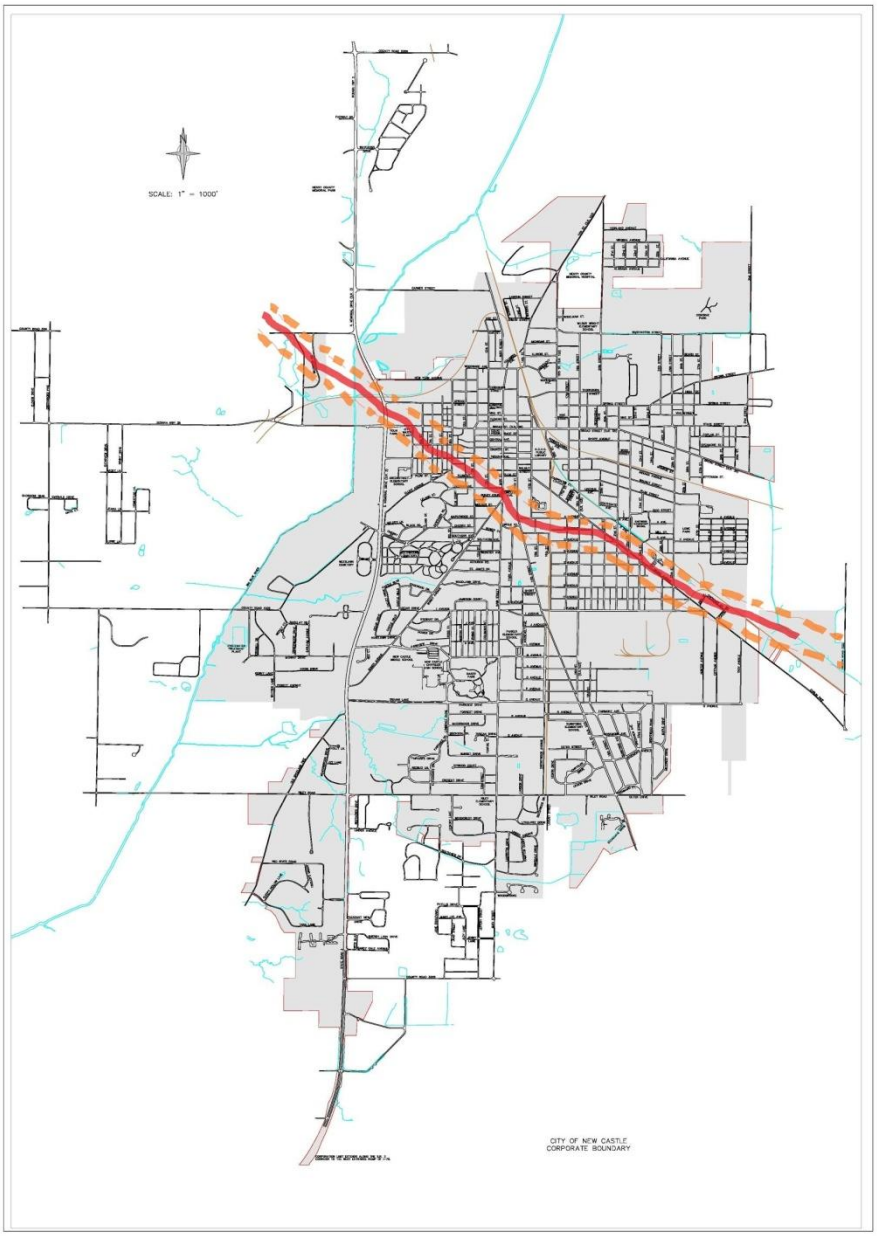

Figure 3: First approximate tornado path, based off secondary sources. The red line is the tornado path, and the orange lines are the "error outlines."

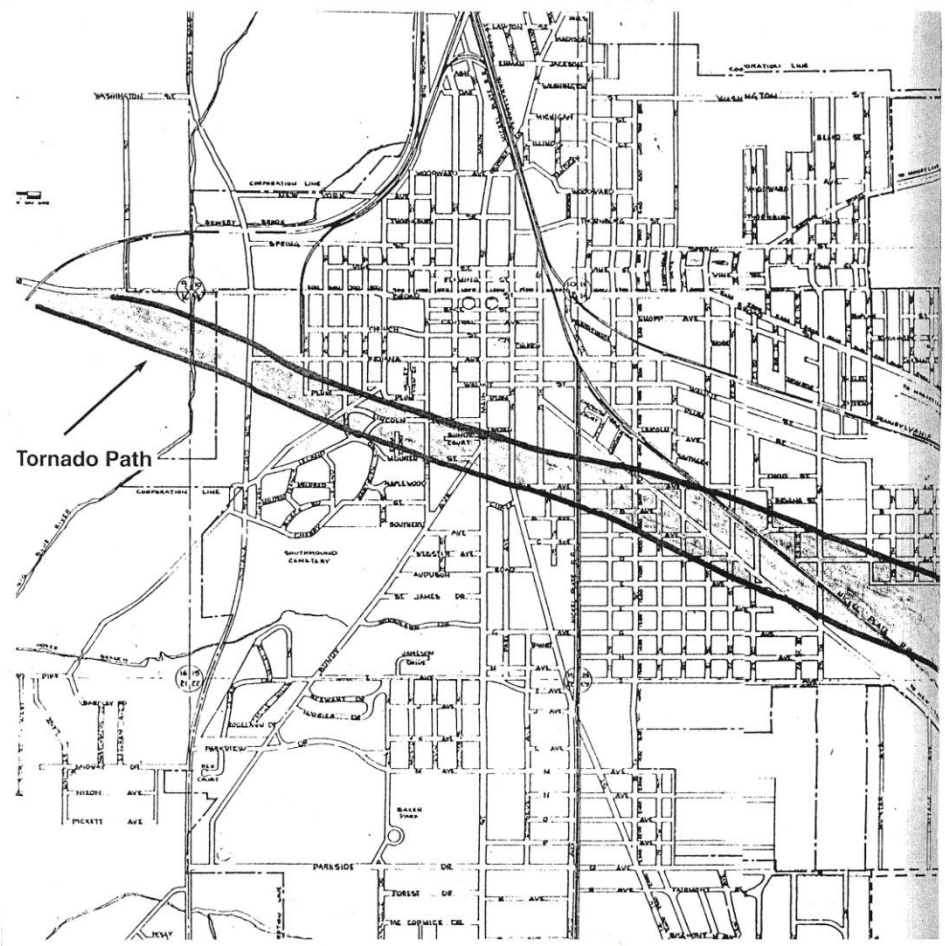

Figure 4: Original tornado path from the Henry County Historical Society.

Figure 5: Damaged homes on East Lincoln Street, indicating the tornado moved through here.

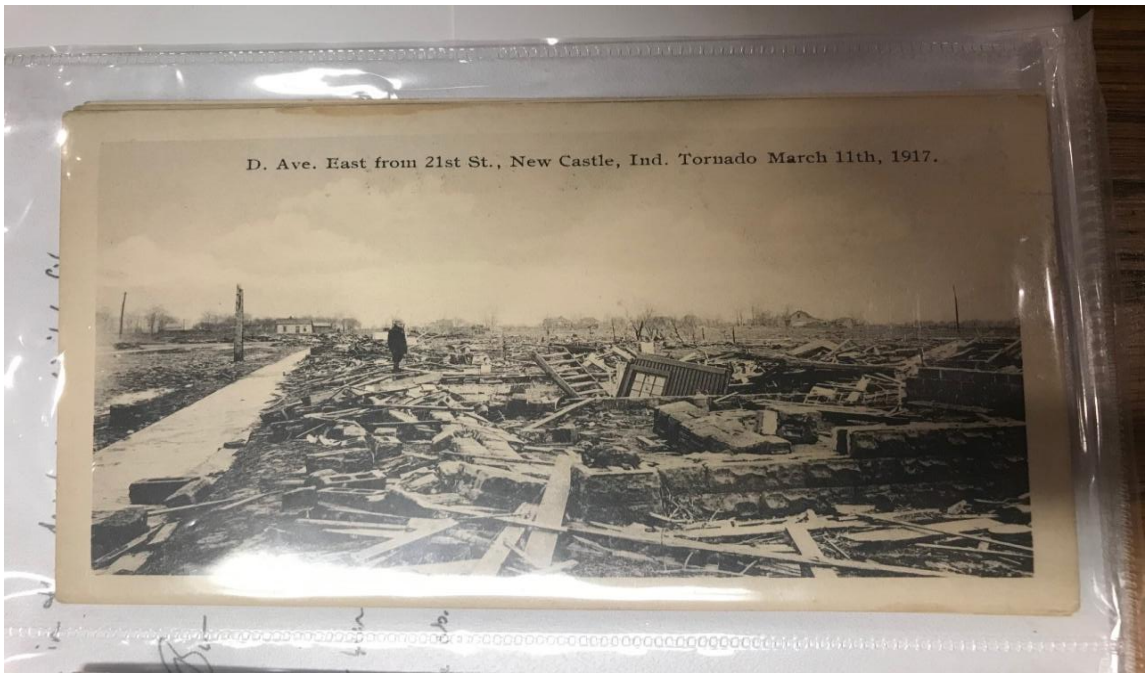

Figure 6: Devastation on D. Ave not only indicates that the tornado was one of the most powerful in Indiana's history, but that most of the destruction on D Avenue was beyond 20th Street.

Figure 7: A. Avenue suffered extreme damage from the tornado as well, with many homes suffering collapsed roofs and walls. While not as bad as in parts of D. Ave. and 20-25th Streets, damage was still severe in A. Avenue.

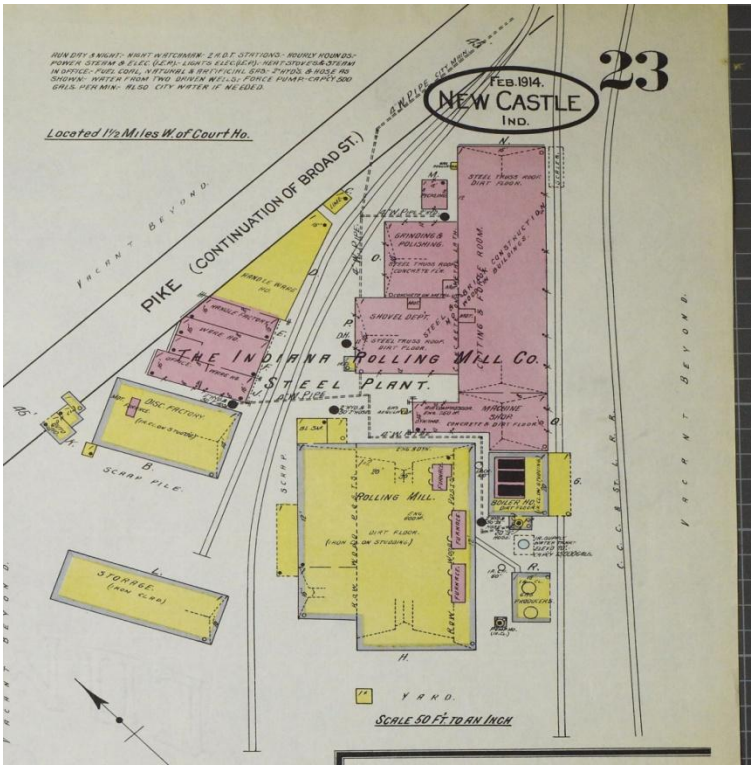

Figure 8: Sanborn map showing the layout of the Rolling Mill plant outside of New Castle. The building is located next to Pike Road, an extension of Broad Street, in New Castle.

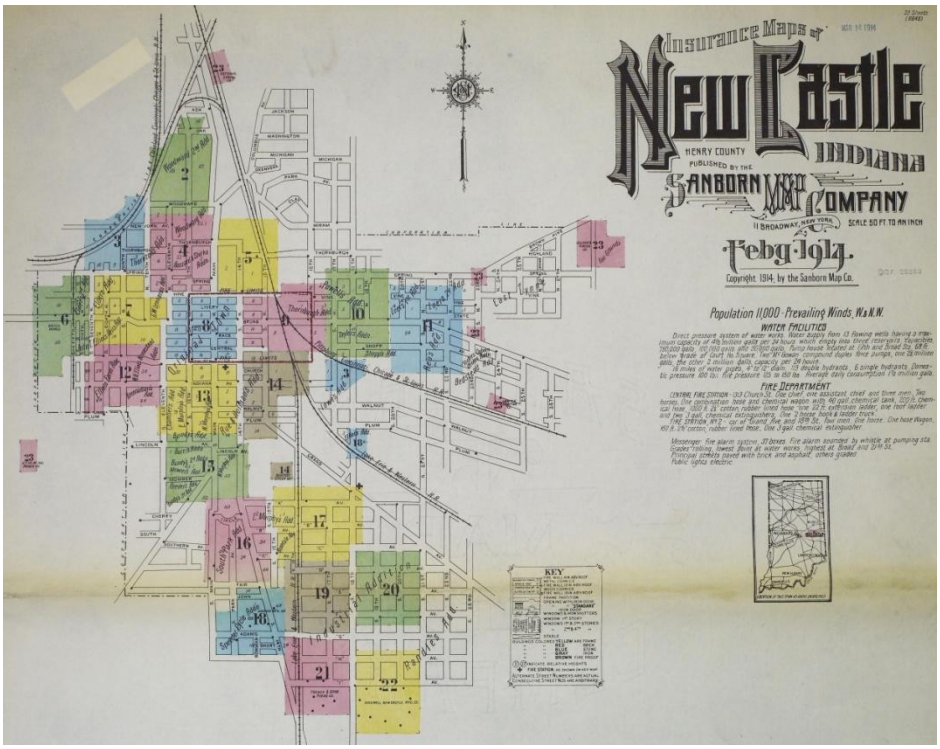

Figure 9: New Castle, 1914. Benthey's Greenhouses are #14, southeast of sections 13 and 14

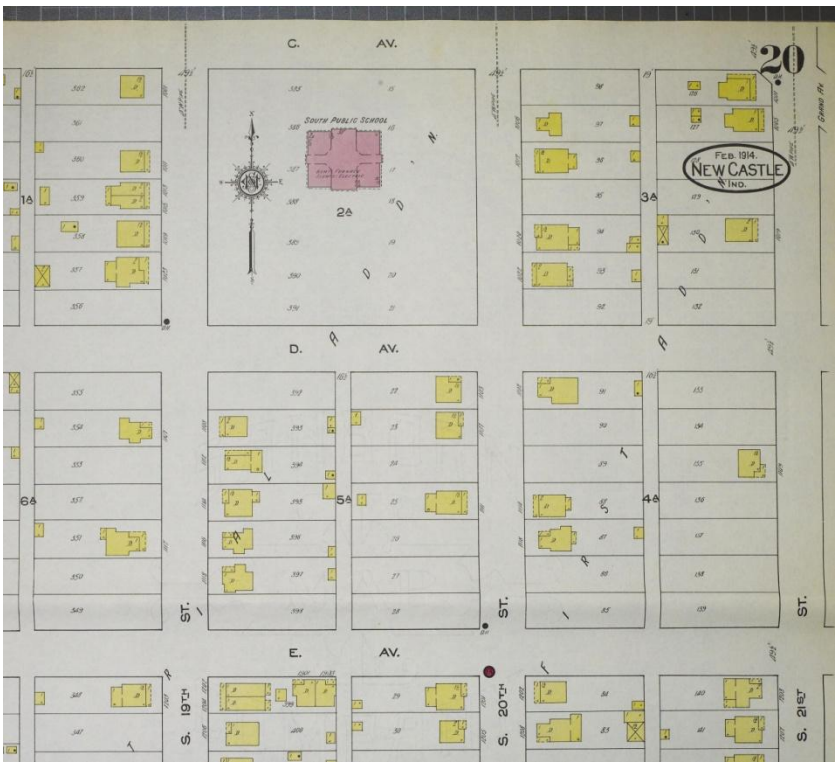

Figure 10: South School was located within C and D Avenues. Both streets suffered multiple instances of tornado damage, so it makes sense that the South School would see damage as well.

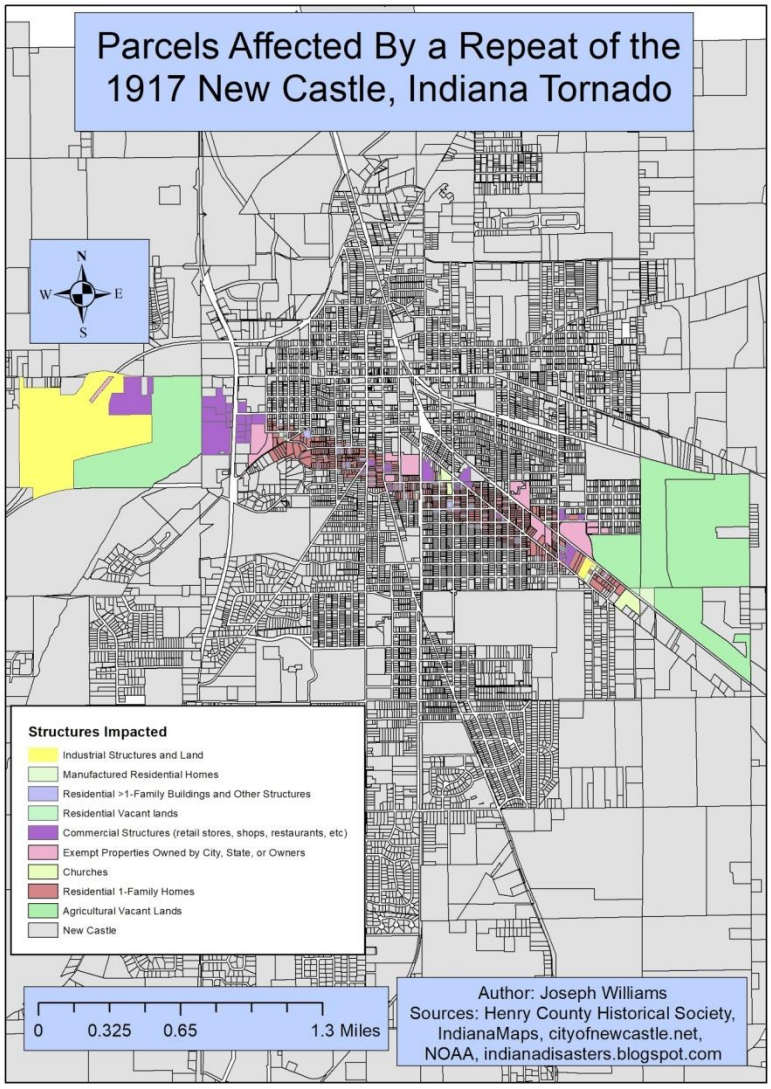

Figure 11: The map shows what kinds of parcels would be in the path of our repeat tornado. Yellow represents industrial structures and land, red and lavender are for residential single-family homes and buildings, and purple represents the commercial structures. Notice the large amount of red throughout the city, implying that most of the parcels affected are residential.

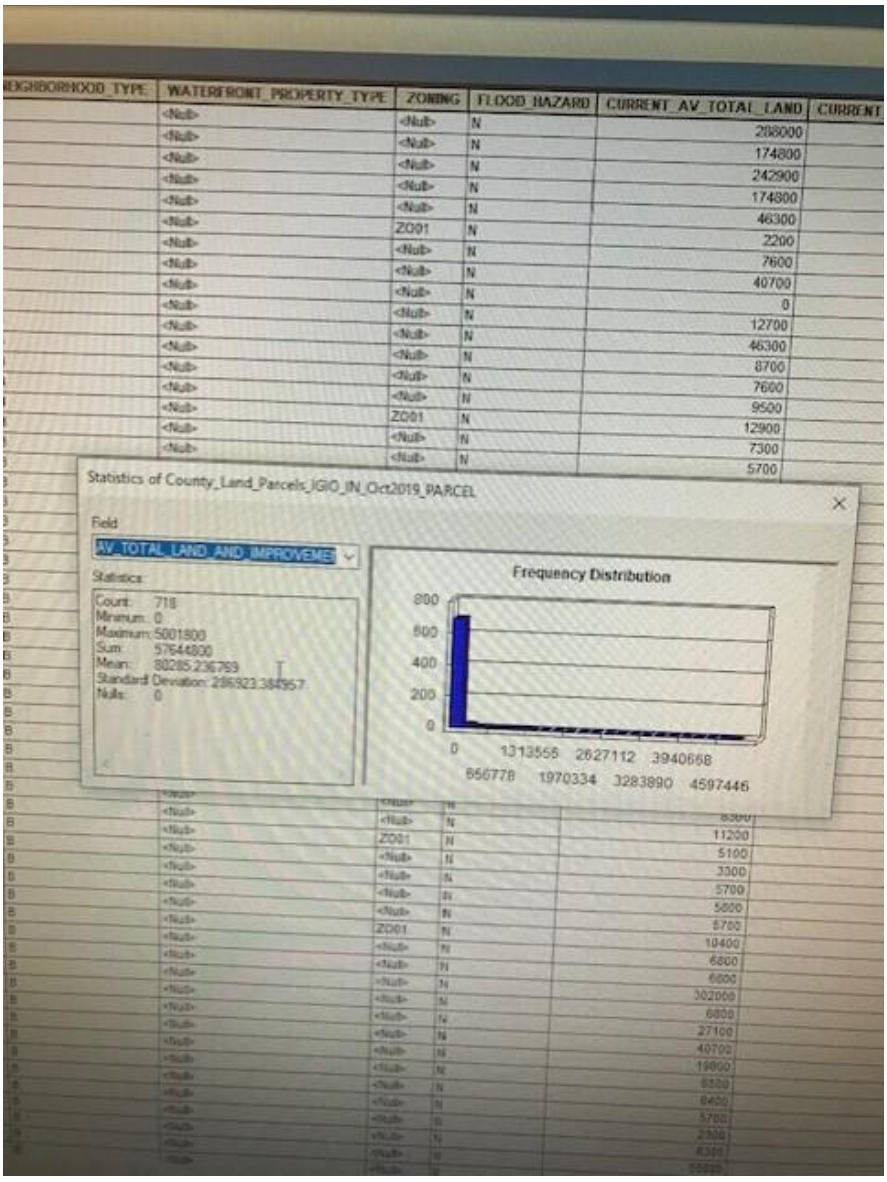

Figure 12: The total costs, in terms of 2018 USD, of the parcel's land and "improvements" - buildings and other structures put on the parcel. The graph shows the number of parcels that have a certain cost to them, e.g. most of the parcels affected cost less than $600,000 USD.

Type of Parcel Impacted	**# of Parcels Impacted**
Residential Single-Family Homes	548
Industrial Structures	4
Exempted Property owned by City, State, or Other	37
Residential >1-Family Homes and Other Structures	60
Commercial Structures	40
Churches and other Places of Worship	5
Agricultural-Vacant Lots	5
Manufactured Residential Homes	5
Residential Vacant Lots	19

Table 1: The number of affected parcels per type of parcel. The total number here is 723, which indicates double counting. This is due to the more simplified categorizing than what the attribute table categorized the parcels as.

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